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ENGINEERING MANUAL:
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ARMY SERVICE FORCES
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ENGINEERING MANUAL



CHAPTER VII
DESIGN OF SANITARY SEWERS,
SEWAGE PUMPING STATIONS AND
SEWAGE TREATMENT PLANTS

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DESIGN OF SANITARY SEWERS, SEWAGE PUMPING
STATIONS AND SEWAGE TREATMENT PLANTS

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CHAPTER VII

DESIGN OF SANITARY SEWERS, SEWAGE PUMPING STATIONS AND SEWAGE TREATMENT PLANTS

PART I GENERAL

7-01. SCOPE OF THESE INSTRUCTIONS: These instructions relate to the collection, treatment and disposal of domestic sewage and such other organic wastes, including laundry wastes, as might be found normally in sanitary sewers serving War Projects of all types. The design of storm water drains is not included in these instructions. Storm water or surface run-off should not be discharged into sanitary sewers.

7-02. INDUSTRIAL WASTES: In general, industrial wastes such as pickling liquids, caustic solutions and other wastes from manufacturing plants should not be combined with domestic sewage and special provision for separate treatment of such wastes should be provided, if treatment is required. However, in certain cases, it may be feasible and economical to combine the domestic sewage with the industrial waste for joint treatment and disposal. The hydraulic factors of design for sanitary sewers also apply to conduits carrying industrial wastes. In some cases, the industrial wastes may be of such nature as to require the use of special materials for conduits.

7-03. DESIGN PROCEDURE: The development of sewer plans, of necessity, must await the final site plan and the completion of field surveys to obtain the necessary topography. In general, however, investigations relating to location of sewage treatment works, the degree of sewage treatment required, the type of plant to be designed, etc., can be completed simultaneously with the development of the site plan. The treatment of sewage is a highly specialized service and a properly qualified sanitary engineer should be employed on the engineering design of the sewage treatment plant.

7-04. ENVIRONMENTAL SANITATION: Where conditions resulting from relatively large increases in population in the vicinity of the project so require, adequate measures for safeguarding public health in the environment should be taken. This may require cooperation with State and local authorities having jurisdiction and with the United States Public Health Service. Among the more important items to be considered are the following: housing, rooming, food supplies, restaurants, milk supplies, waterworks, sewerage and sewage disposal, public comfort stations, garbage and refuse collection and disposal, and street cleaning. Particular attention should be given to any shallow water or swampy areas within one mile of the project, and proper provisions made for mosquito abatement. Consideration of such conditions should be given during the construction period as well as the period of occupancy.

7-05. TEMPORARY DISPOSAL OF SEWAGE: In some instances, temporary treatment of sewage is necessary at War Projects during the construction period, or to provide for occupancy of the project prior to the completion of the sewage treatment plant.

a. Sedimentation and Chlorination: Whenever possible construction should be scheduled to provide for the completion of the primary sedimentation tanks so that these can be placed in service prior to the completion of the remainder of the plant and the sewage given partial treatment. In such cases it is usually possible to provide chlorination for the sterilization of the sedimentation tank effluent prior to discharge into the receiving water course. In cases where it is necessary to provide temporary treatment prior to the completion of any portion of the

sewage treatment plant it may be necessary to construct a septic tank at a convenient location and arrange for applying chlorine to the tank effluent at the rate of 100 pounds per million gallons. Such a septic tank can be excavated in earth, lined with timber sheeting and provided with a wooden roof. The cost of the temporary installation should be kept at a minimum and reliance placed on the heavy chlorination (at the rate specified above) of the tank effluent to prevent a local nuisance and menace to health.

b. Plain Sedimentation and Lime Treatment: A relatively high degree of purification can be obtained by the application of hydrated lime to the raw sewage at the plant inlet. This requires the installation of a chemical feeder to feed the lime. Mixing of the lime with the sewage can be accomplished through a Parshall Flume. Sufficient lime should be added to develop a causticity of 10 to 20 p.p.m. This will result in the precipitation of the calcium and magnesium bicarbonates, which when settled will carry with them the suspended solids of the sewage. The amount of lime required will vary from 500 to 1500 pounds per million gallons of sewage depending on the hardness of the carriage water. This treatment will result in the removal of approximately 80 to 90 per cent of the suspended solids and a reduction of total bacteria in the same proportion. The reduction in B.O.D. will be from 60 to 70 per cent. This treatment can be used in conjunction with the primary sedimentation tanks if they are completed or the settling may be accomplished in a temporary septic tank, such as that described in 7-05 a above and shown on Exhibit No. 2. The volume of sludge to be handled will be substantially greater than the amount of settleable sludge solids because of the mineral precipitates but since the sludge is caustic it can be pumped into lagoons or burial pits without serious nuisance. If the digestors are completed they can be used to receive the lime treated sludge. This sludge will be beneficial in promoting alkaline digestion after the plant is placed in normal operation. The excess lime treatment followed by plain sedimentation is not considered desirable for permanent treatment. Large quantities of lime would be required and the discharge of heavily treated effluents over a period of time would result in the accumulation of lime deposits in the receiving water course.

7-06. USE OF EXISTING SEWAGE TREATMENT PLANTS:

a. Municipal Plants: For War Projects located adjacent to fairly large cities, investigation should be made of the city's sewage facilities to determine whether they are large enough to handle the flow from the project, assuming a reasonable increase in city requirements, and whether the city officials are favorably inclined toward handling the sewage at a reasonable cost to the Government for such services. These investigations should cover the practicability of such a connection and whether the sewage will require pumping, or can be delivered to the city's system by gravity.

b. Government Plants: If there is an existing sewage treatment plant under the jurisdiction of the War Department, or other Governmental Agency, which is accessible and which might be suitable with or without enlargement, an investigation should be made to determine its capacity and condition and the possible arrangements that might be made for its use.

7-07. SITE SELECTION FOR SEWAGE TREATMENT PLANTS: Sites for sewage treatment plants should be carefully selected. The topography and location of the receiving stream will usually determine the location. Plants should preferably be located as far as practicable from buildings, private dwellings and travelled ways and consideration should be given to the direction of prevailing winds. Plants should be located where they will not interfere with military operations and should be at a safe distance from rifle and artillery ranges. If possible, sites should be located above high water, but flood protection should be provided if required. Sufficient space should be available for a convenient arrangement of plant structures and for possible future extensions to the plant.

7-08. DEGREE OF TREATMENT AND SELECTION OF DESIGN FACTORS:

a. General: The sewage treatment plant should, if practicable, be designed to meet the requirements of local and State Health Departments, particularly as to degree of treatment and disposal of effluent and to this end the State Sanitary Engineer, or Director of the State Department of Health, should be consulted.

b. Factors Affecting Treatment: The degree of treatment required will depend upon the amount of diluting water available in the receiving stream during periods of minimum flow, the condition of the stream as regards pollution, and the use of the stream below the proposed point of discharge. Consideration should also be given to local practice with regard to the degree of treatment being provided by existing plants and the anticipated period of occupancy of the project.

c. Partial Treatment: Where the effluent from the sewage treatment plant is to be discharged into a relatively large stream with a flow sufficient to provide a minimum dilution of about four (4) c.f.s. of stream flow per 1,000 population, sedimentation tanks with chlorination will usually be sufficient. This partial degree of treatment may be suitable in cases where the effluent is to be discharged into tidal waters, or finally disposed of by irrigation on land.

d. Design Factors: If a greater degree of treatment is required, consideration should be given to operating requirements and the simplest type of plant should be used that will give the desired results. Where more than partial but less than complete treatment is required single stage high capacity filters can be used to good advantage. Treatment by the activated sludge process, standard rate trickling filters or multi-stage high capacity filters will provide complete treatment where required. See paragraph 7-09 below.

7-09. CONSERVATION OF CRITICAL MATERIALS: Current policies of the War Department with respect to the conservation of critical materials must be strictly observed in the design of sewerage systems and sewage treatment works. Plants should be simplified as much as possible and preference given to designs and types of treatment which require the use of a minimum amount of mechanical equipment, reinforcing steel and other items of critical materials. Where filter stone can be secured at a reasonable cost, standard rate filters, requiring a minimum amount of mechanical equipment, should be given preference. The use of high capacity filters and other types of treatment requiring greater amounts of mechanical equipment and other critical materials should be confined to localities where stone is not available or where space limitations and other factors require the use of such processes. To avoid delays in securing delivery of equipment, every effort should be made to utilize types of equipment which can be supplied by several manufacturers. It is essential that sewage treatment facilities, where definitely needed, be ready for operation at the time of initial project occupancy. The ability of equipment manufacturers to make delivery within the required time must be carefully investigated prior to making commitments for the purchase of mechanical equipment.

PART II
SANITARY SEWERS

7-10. DEFINITIONS:

- a. Sewerage Works: All construction for collection, transportation, pumping, treatment and final disposition of sewage.
- b. Collecting System: All sewers and appurtenances from the house to the outfall.
- c. House Sewer: A pipe conveying the sewage from a single building to a common sewer or point of immediate disposal.
- d. Lateral Sewer: A sewer which discharges into a branch or other sewer and has no other common sewer tributary to it.
- e. Branch Sewer: A sewer which receives sewage from a relatively small area.
- f. Main Sewer: A sewer which receives one or more branch sewers as tributaries.
- g. Trunk Sewer: A sewer which receives many tributary branches and serves as an outlet for a large territory.
- h. Force Main: A pipe line carrying sewage under pressure from a sewage pumping station.
- i. Outfall Sewer: A sewer which receives the sewage from the collecting system and conducts it to a point of final discharge or to a disposal plant.
- j. Outlet Pipe: A pipe which conveys the effluent from a treatment plant to its final point of disposal.
- k. Inverted Siphon: A sewer depressed below the hydraulic grade line so that the pipe or pipes are full at all times. NOTE: Pipe sizes should be so selected as to provide flow velocities sufficient to prevent deposits or to scour out any deposits which might develop.

7-11. SPECIFICATIONS: Current issue of Section XXVII, Specifications for Theater of Operations (Modified) and Mobilization Construction for Sanitary Sewers, Office of the Chief of Engineers, will be followed, insofar as applicable, to the materials selected. In cases where the materials and methods, approved for the work, are not covered by these Specifications, suitable specifications for the work should be prepared.

7-12. STANDARD DETAILS: Standard details of construction items are shown on Standard Drawing No. 672-243, O.C.E. These standard details may be modified to fit local conditions where such modification is desirable, subject to the approval of the District Engineer.

7-13. BASIS OF DESIGN:

a. Sewage Quantities: Average daily sewage flows to be used for the design of collecting lines may be assumed as follows:

Type of Unit	Gallons per Capita per Day			
	Permanent Posts	Mobilization Type	T. of O. Type	Field Training Camps
Airfields, Camps, Cantorments and Troop Facilities	100	70	50	35
Hospital Units	100	100	85	70
Plant, Port and Storage Projects (Civilian War Workers)		30 per 8 hour shift 100 for resident personnel		

Where unusual ground water conditions are known to exist an allowance of 10,000 gallons per mile of sewer per day may be added to the above for infiltration.

(NOTE: The above per capita sewage quantities include laundry waste incidental to laundering for the resident population and no additional allowances will be made for such waste except in special cases. It is anticipated that the sewage treatment plant will be capable of treating the laundry waste together with the sanitary sewage and pretreatment of laundry waste will be provided only where specifically authorized. Standard plans for the construction of plants for the pretreatment of laundry waste will be furnished where such treatment is authorized.)

b. Peak Flow for Sewer Design: The tributary population will be based on the full capacity of all buildings within the tributary areas and will include all civilian personnel. For plant, port and storage projects determination of peak flows should take into consideration maximum rates during the period the greatest number of workers are on duty. All sewers should be designed to handle peak flows based on the following:

Tributary Population	Ratio of Peak To Average Flow
1,000	3.7
2,000	3.66
3,000	3.62
5,000	3.55
7,000	3.47
10,000	3.34
15,000	3.18
20,000	3.05
30,000	2.79
35,000	2.70
40,000	2.58
50,000	2.55

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c. Future Capacity: Additional capacity to provide for population increases will not be considered for lateral and branch sewers where the areas served are fully developed. In the design of long outfall sewers and main sewers serving areas susceptible of further development additional capacity should be provided by applying the capacity factors set out in Paragraph 7-37.

7-14. SIZES AND SLOPES:

a. Size: House sewers should not be less than 6 inches in diameter. The minimum size of sewers other than house sewers should be 8 inches.

b. Slopes: In general, all sewers should be laid on slopes sufficient to provide a minimum velocity of 2 feet per second when flowing full or half-full. However, in unfavorable terrain, velocities of 1.5 feet per second may be used if excessive depths of sewer trench or the use of sewage lift stations can be eliminated thereby. The following slopes for various sizes of sewers will produce satisfactory velocities:

Diameter in Inches	Slope in ft./1000 ft. for Velocity of 2 ft./sec.	Slope in ft./1000 ft. for Velocity of 1.5 ft./sec.
6	6.0	3.6
8	4.0	2.3
10	2.9	1.6
12	2.2	1.2
15	1.5	0.86
18	1.2	0.67
21	0.95	0.53
24	0.80	0.44
27	0.67	0.38
30	0.58	0.33

(NOTE: There is a tendency on the part of some designers to increase the size of the sewer where flat grades are required in order to maintain a theoretical minimum velocity of 2 feet per second. Actually the increased pipe size will result in a decrease in a depth of flow such that the resultant velocity is no more than would be obtained by using the smaller sewer at the same slope. The net result of increasing the pipe size is to increase the cost and this practice should be avoided.)

c. Hydraulic Design: Design capacities of sewers should be computed by Kutter's formula using $n = 0.013$ with pipe flowing full. A diagram (See Exhibit No. 1) giving discharge of pipes by Kutter's formula, $n = 0.013$, is inserted herein for ready reference.

7-15. SEWER LAYOUT AND ARRANGEMENT OF STRUCTURES:

a. Sewers: Where otherwise feasible, sewers should not be built longitudinally under paved roadways, and pavement crossings should be kept to the minimum. The cutting of roadways for house sewers should be avoided where practicable. At railroad crossings, special construction consisting of metal pipe or sewer pipe encased in concrete should be used. *Sewer mains will not be installed in the same trench with water mains, but shall be located six (6) feet or more from them horizontally and on opposite sides of roadways where practicable. Where sewer and water mains cross, the sewer will, if possible, be located below the water main. If conditions necessitate, a gravity sewer may cross over a water main, provided the sewer for ten (10) feet either side of the crossing is constructed of cast iron, steel or other pressure pipe. Sewers under pressure such as force mains, inverted siphons, etc., will in all cases cross under and be installed not less than two (2) feet below the water main.*

*Single asterisks appear before and after new or revised material.

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b. Manholes: Manholes should be constructed at the end of each lateral, and at each change of direction, slope or grade. The distance between manholes should not exceed 400 feet, except on long outfall sewers of larger pipe sizes where distances of 600 feet between manholes may be used.

c. Flush Tanks: Flush tanks are not considered advisable or necessary in sanitary sewer systems and will be used only in connection with Types Lt-F-T and Lt-G-T Latrines as shown on Standard Drawings Numbers T.O.-700-6625 and T.O.-700-6626.

d. Cover: In general, sewers should not have less than 2 feet of cover to provide protection from traffic. For allowable sewer trench loadings see Paragraph 7-20.

e. Limitations on Use of Sanitary Sewers: The following wastes should not be permitted to enter the sanitary sewers, but should be discharged through separate drains:

- (1) Storm water.
- (2) Waste water from hydraulic gasoline storage systems.
- (3) Waste water from garage and shop floor drains.
- (4) Waste water from wash racks.

f. Cross-Connections: There shall be no possible or actual physical connection between sewer and water supply systems.

g. Building Connections: All building connections into sewer lines less than 24 inches in diameter should be made only with commercially manufactured Wye branches or Tees. Where convenient, such connections may be made directly into manholes. The house sewer will be separated not less than six (6) feet horizontally from the water service pipe.

7-16. GREASE TRAPS: The removal of grease is necessary for the proper functioning of sewage treatment plants and will be accomplished by the installation of grease traps in mess halls and kitchens as outlined in Chapter XIV, Interior Utilities, of this Manual and specified in Section XXXV, Specifications for Theater of Operations (Modified) and Mobilization Construction for Plumbing, Office of the Chief of Engineers.

7-17. MATERIALS FOR SANITARY SEWERS:

a. Type of Materials: In the selection of materials for sanitary sewers, full consideration will be given to initial economy, speed of construction and the availability of local materials. In general, camps and cantonments are considered temporary construction and underground utilities should be constructed of materials to provide a useful life of at least five years. Vitrified clay sewer pipe may be used in all sizes for which it is readily available. Unreinforced concrete sewer pipe may be used, in competition with vitrified clay, for sizes 24-inch and smaller, except where local conditions indicate that its use is inadvisable. Reinforced concrete pipe may be used for sizes over 24-inch, except where conditions are known to exist which would cause the severe disintegration of this material.

b. Concrete Sewer Pipe: Conditions under which concrete pipe may not be used are as follows:

- (1) Where the sewer receives acid waste not sufficiently diluted with alkaline sewage.
- (2) Where acid subsoil may gradually attack and destroy the pipe, i.e., cinder fills.
- (3) Where local experience has indicated that concrete sewer pipe is not suitable.

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c. Pipe Alternates: Where conditions indicate either vitrified clay sewer pipe or Portland Cement concrete pipe will be acceptable, specifications should be so drawn as to permit the use of either or both types. Where warranted by conditions of availability and economy, other materials may be used on approval by the District Engineer. District Engineers should make the following investigations to satisfy themselves as to:

- (1) Whether Portland cement concrete pipe has been installed in municipalities near their respective projects and has given satisfactory results.
- (2) Whether aggregates meeting Federal Specification No. SS-A.281, Grade "A" requirements, are available.
- (3) Whether manufacturers can comply with the Specification requirements as to machine manufacturing and curing.
- (4) Whether, if both types (vitrified terra cotta and cement concrete pipe) are specified, competition can be had.

7-18. SEWER PIPE JOINTS: Sewer pipe joints should preferably be made with hot poured bituminous material, preformed bituminous or plastic bituminous material. Cement mortar may be used on approval by the District Engineer.

7-19. MANHOLES:

a. Manhole Walls: Manhole walls may be constructed of brick masonry, concrete block masonry or unreinforced monolithic concrete, depending on availability of materials, skill of available workmen and other considerations affecting economy.

b. Manhole Foundations: Manhole foundations shall be of unreinforced concrete.

c. Invert Channels: Invert channels may be formed in the concrete, built up with brickwork and mortar, constructed of half-tile, or made by laying pipe straight through the manhole with the top half broken out and removed after construction. The most practical and economical method under local conditions shall be used.

d. Manhole Steps: In order to conserve metal, manhole steps should be omitted wherever possible. Access can be had by the use of a ladder. Where manhole steps are necessary they may be cast iron, wrought iron or ordinary steel rods. If cast iron they should be of a pattern readily available locally. If wrought iron or steel rods are used they should be not less than 3 1/4-inch diameter.

e. Manhole Frames and Covers: To conserve critical materials reinforced concrete frames and covers should be used in locations subjected to traffic. Unreinforced concrete and wood covers may be used in locations not subjected to traffic.

7-20. SEWER TRENCH LOADING: Where the loads in the sewer exceed those that can be safely carried by the pipe, and where required for wet soil conditions, concrete cradles will be used. Sewer trench loadings should be computed by the Marston-Anderson Formula as developed in Bulletin 96, Iowa State College, Engineering Experimental Station, which is as follows:

$$W = CwE^2$$

where

W = dead load on the pipe in pounds per lineal foot.

W = weight of ditch filling material in pounds per cubic foot, taken from Table B below.

E = breadth of ditch in feet at the top of the pipe.

H = height of fill in feet above the top of pipe.

C = coefficient of load on pipe in ditches determined from the following Table A.

TABLE A

Ratio of depth to width H/B	Value of the Coefficient C for Use in the Marston-Anderson Formula			
	Damp Top Soil and dry and wet sand	Saturated Top Soil	Damp Yellow Clay	Saturated Yellow Clay
2.5	1.70	1.77	1.83	1.91
3.0	1.90	1.99	2.08	2.19
3.5	2.08	2.18	2.28	2.43
4.0	2.22	2.35	2.47	2.65
4.5	2.34	2.49	2.63	2.85
5.0	2.45	2.61	2.78	3.02
5.5	2.54	2.72	2.90	3.18
6.0	2.61	2.81	3.01	3.32
6.5	2.68	2.89	3.11	3.44
7.0	2.73	2.95	3.19	3.55
7.5	2.78	3.01	3.27	3.65
8.0	2.82	3.06	3.33	3.74
8.5	2.85	3.10	3.39	3.82
9.0	2.88	3.14	3.44	3.89
9.5	2.90	3.18	3.48	3.96
10.0	2.92	3.20	3.52	4.01
11.0	2.95	3.25	3.58	4.11
12.0	2.97	3.28	3.63	4.19

TABLE B

VALUES OF "w" WEIGHTS OF DITCH FILLING MATERIAL
For
USE IN MARSTON-ANDERSON FORMULA

<u>Material</u>	<u>Wt. of Filling per Cubic Foot</u>
Partly compacted damp yellow clay	100
Dry Sand	100
Saturated Top Soil	110
Wet Sand	120
Saturated Yellow Clay	130

NOTE: Allowances for live loads over sewer trenches are not made except under railroad tracks and other locations where metal pipe, concrete encasement or a protective conduit is required.

7-21. FORCE MAINS: Sewage force mains will be constructed of cement asbestos, wood stave, cast iron or steel pipe of adequate strength to withstand the internal pressures and external loads, and shall be water-tight. The line must be large enough to handle peak rates of flow without excess loss of head due to friction. In general friction losses through long force mains should not exceed 100 feet when the combination of pumps producing the maximum discharge are in operation. Consideration will be given to venting all summits in force mains, to providing drainage at low points, and to protecting against surge in long lines.

7-22. LAYOUT MAPS: A layout map showing the entire collecting system, together with unit maps to a scale of 1 inch to 50 feet, should be prepared. Distribution of sewer layout maps should be as provided in Section 1, Chapter XXIII of this Manual.

7-23. DESIGN ANALYSIS: A design Analysis, required by Paragraph 703.33 a (Revision of November 2, 1942) Orders and Regulations, Corps of Engineers, will be prepared to accompany all plans and specifications for sanitary sewers. The design analysis will indicate the total tributary population to be served by each main sewer and the method used in determining sewer sizes.

PART III SEWAGE PUMPING STATIONS

7-24. GENERAL: Sewage pumping stations may be required to pump the sewage from areas which cannot be served by the main gravity system or at sewage treatment plants where pumping is required to handle the sewage through the plant. Sewage pumping stations, in general, will comprise a screen, a sump or storage well and a dry well for the pumping equipment.

7-25. LOCATION OF SEWAGE PUMPING STATIONS: The location of sewage pumping stations serving portions of a system will usually be determined by the topography. Such stations should be located as far as practicable, from buildings, but should be readily accessible from an improved road. Sewage pumping stations at treatment plants will usually be constructed adjacent to and in connection with the other plant elements.

7-26. PUMPING STATION CAPACITY:

a. Rates of Sewage Flow: The average rate of flow for which pumping capacity is to be provided should be based on the per capita sewage flows stated in Paragraph 7-12 g above. The capacity of the pumping station should be ample to handle maximum rates of sewage flow as outlined in Paragraph 7-12 b above. The design should be such that there will not be long intervals between the operation of a pump during periods of minimum flow, especially if such intermittent discharge will adversely affect the operation of a sewage treatment plant by introducing high rate flows at infrequent intervals.

b. Reserve Capacity: Additional capacity to provide for population increases will not be considered for sewage pumping stations serving areas which are fully developed. If the pumping station serves an area which may be expanded it is wise to provide space in the building for the installation of an additional or larger pump at a later date. In the design of sewage pumping stations constructed in connection with sewage treatment plants additional capacity should be provided by applying the same Capacity factor used in the design of the sewage treatment works.

7-27. SELECTION OF PUMPING UNITS: Horizontal or vertical centrifugal pumps are usually best suited for sewage pumping installations. For small stations serving populations less than 1500, twin pneumatic sewage ejectors or ejector type pumps are acceptable and may be used in lieu of centrifugal pumps. The use of the ejector type of equipment eliminates the need of screens and the units can frequently be installed in a pit entirely below ground thereby eliminating the need of a pumping station. For stations serving populations of 5,000 or less, two pumping units, each capable of handling the maximum rates of sewage flow will probably suffice. For stations serving populations greater than 5,000 three or four pumping units will be required, depending on the head capacity characteristics of the station as a whole. The minimum size of centrifugal pumps should be such as to pass a 2-inch sphere with 4-inch suction and discharge, piping and valves. All pumps will normally be actuated by float controlled switches.

7-28. STORAGE WELL: The storage well should be carefully designed to eliminate the possibility of sludge deposits. In order to prevent the sewage from becoming septic due to long retention during periods of minimum flow the capacity of the storage well should be large enough only for the proper operation of the pumps. For pumping stations serving a population of less than 3500 the storage well should provide about ten minutes storage at the average rate of flow. For stations serving a population greater than 3500 storage of three to five minutes at the average rate of flow is sufficient.

7-29. PUMP CHARACTERISTICS: If the pumps discharge into an adjacent conduit of ample size or directly into the primary sedimentation tank at the sewage treatment plant there will be no increase in friction head when pumping at increased rates of flow and all pumps in the station may be operated together to deliver the peak rates of flow. If the pumps discharge into a long force main there will be an increase in friction head when the rate of flow is increased. This will create a total head higher than the rated head of the individual pumping units so that not more than one or possibly two pumps will be capable of operating effectively at one time. Under such conditions it will be necessary to provide one pump having head capacity characteristics capable of handling the maximum rate of flow.

7-30. OVERFLOWS: Whenever possible an overflow should be provided from the storage or sump well to a point of outlet to operate only in case of power outages or short periods of shutdown. The elevation of the overflow must be low enough to prevent the backing up of sewage into buildings. Generally the operation of an overflow into an adjacent water course during a power outage will not create a serious menace to public health because of the infrequency of use and the overflow should be omitted only in cases where a water supply would be definitely endangered.

7-31. STANDBY POWER: Standby power will be required only where it is impossible to provide a suitable overflow. Where standby power is required one pumping unit capable of handling the peak flow should be equipped with a combination head and standby gasoline engine.

7-32. SURGE PROTECTION: When the location of the pumping station requires a force main of several thousand feet, provision should be made for protection against surge and for drainage of the force main. A suitable air chamber at the pumping discharge will usually provide adequate surge protection.

7-33. DESIGN ANALYSIS: A design Analysis, required by Paragraph 703.33 a (Revision of November 2, 1942) Orders and Regulations, Corps of Engineers, will be prepared to accompany all plans and specifications for sewage pumping stations. The design analysis will indicate the total tributary population to be served by the pumping station and the basis of design for each component unit.

PART IV SEWAGE TREATMENT PLANTS

7-34. GENERAL: The basic design data contained herein applies to the planning of sewage treatment plants of all sizes. It is important that designs be simplified as much as possible and preference given to types of treatment which require the use of a minimum amount of mechanical equipment, reinforcing steel and other items of critical material. It is anticipated that sewage treatment plants will be capable of treating the normal laundry waste together with the sanitary sewage. Plants for the pretreatment of laundry waste will be considered only at locations where existing treatment works are overloaded and where the pretreatment of the laundry waste will make it unnecessary to enlarge the sewage treatment plant. At certain Ordnance Plants and Chemical Warfare Plants there may be unusual industrial wastes which require special treatment involving the neutralization of chemical compounds used in the manufacturing processes.

7-35. ELEMENTS OF SEWAGE TREATMENT PLANTS: Listed below are the elements that make up sewage treatment plants. A plant designed to give partial treatment may include screens, grit chambers, measuring devices, all of the types of preliminary sedimentation tanks listed under subparagraph d of 7-58, "Chlorination," all of the sludge disposal facilities listed under h and the auxiliary items listed under i and j below. A plant designed to provide complete treatment will include in addition to the above one of the biological processes listed under subparagraph e below and one of the types of final sedimentation tanks listed under subparagraph f. It will be seen that a treatment plant may consist of a number of different combinations of treatment methods.

a. Screens: Screens remove large suspended and floating matters, such as sticks, rags and miscellaneous materials that would clog pumps or cause excessive scum.

b. Grit Chambers: Grit chambers remove sand and similar heavy gritty materials that would injure pumps or clog sludge pipes.

c. Measuring Devices: These devices measure the amount of sewage flowing into or out of the plant. In large plants sludge may also be measured. Such measurements provide valuable information to the plant operator and lead to obtaining better effluents.

d. Preliminary Sedimentation Tanks: These remove a large proportion of the settleable solids and thus reduce the load of organic solids preliminary to treating the partially clarified sewage by biological means.

(1) Plain or Single-story with sludge removing equipment: These tanks allow the solids to settle on the tank bottom where moving blades push it to a hopper at the center or at one end. From there the sludge is pumped or drawn by gravity to the sludge digestion tank.

(2) Plain or Single-story with Hoppered Bottoms: These tanks allow the sludge to settle into hoppers from which it is withdrawn to the sludge digestion tank.

(3) Imhoff or Two-story: These tanks have an upper story which serves as a sedimentation tank. It has a V-shaped bottom with a slot at the point of the V through which the solids settle to the lower story. In the lower story the sludge is retained until it is digested.

e. Biological Processes: These are also known as secondary treatments because they provide opportunities for bacteria to stabilize or oxidize the organic matter remaining in the sewage after the preliminary treatment. They allow intimate contact with a medium that contains a bacterial growth and obtains oxygen from the atmosphere.

(1) Standard or low capacity trickling filters: These are beds of crushed rock, gravel, or slag of relatively large size. The sewage trickles in a thin film over the stones which are coated with an organic film containing the aerobic oxidizing bacteria.

(2) High capacity trickling filters: The only important differences between these and the standard filters are the greater dosing rate and the provision for recirculating filtered effluent back through the filter. Some filters may have provision for forcing air through them. These filters depend more upon coagulation of colloidal sewage solids for their efficiency than do standard filters. More careful design of final settling tanks is therefore required.

(3) Activated Sludge: In the activated sludge process settled sewage is passed through aeration tanks where it is brought into contact with previously developed activated sludge. Activated sludge is created by aerating with compressed air blown into it or by mechanical agitation or by a combination of these methods. The sludge contains aerobic bacteria which act upon the organic matter. The sludge assimilates some of the organic matter and constantly increases in volume. The activated sludge is settled out in the final sedimentation tank, a portion of it being returned and mixed with the incoming settled sewage and a portion of it wasted to the digestor.

(4) Contact-aeration: In this treatment the sewage passes through a tank containing submerged plates or large stones. Air is applied at the bottom of the tank and the rising bubbles set up aerobic conditions and promote an organic film on the surfaces which stabilize the organic matter of the sewage.

(5) Other approved processes: These include sand filters, sub-surface irrigation and leaching pools. They are useful under favorable conditions and for small installations.

f. Final Sedimentation Tanks: These tanks separate coagulated solids or sludge, if treatment is by (e) above, from the sewage, leaving the clear, stabilized liquid as the effluent.

(1) Flat-bottomed Tanks: Tanks with sludge moving equipment are the same as those described under subparagraph d (1) above.

(2) Hopper-bottomed Tanks: These are the same as those described under subparagraph d (2) above.

g. Chlorination Plant: Chlorination has several uses in sewage treatment. When used as a disinfectant it is usually applied in the effluent to kill pathogenic organisms remaining after other treatments. When used to prevent odors at the plant it is applied to the raw sewage where it both inhibits the growth of bacteria which form odorous gases and neutralizes those already formed.

h. Sludge Disposal Structures: Sludge is a by-product of all of the processes of subparagraphs d, e, and f above. It is unstable, large in quantity and high in water content. It is usually stabilized and reduced in quantity by anaerobic bacteria in digestion tanks.

(1) Digestion Tanks: These are tanks which hold the sludge for the 6 to 12 weeks necessary for anaerobic digestion. Digested sludge is withdrawn from time to time from the bottom of the tank. Heating makes it possible to keep the sludge at the optimum temperature for more rapid digestion.

(2) Sludge Pumping Facilities: These are necessary to return activated sludge to the aeration tank; to remove sludge from sedimentation tanks to the digestion tank; or to remove sludge from the digestion tank to the sludge drying bed. Some of these processes in any one plant may be accomplished by gravity flow.

(3) Sludge Drying Beds: After digestion sludge is inodorous and drainable. Sludge drying beds are constructed of sand underlain by gravel, and drained by open-jointed tile pipes. Sludge is run onto the bed and water drains away or is evaporated.

i. Plant Sewers and Piping: These comprise all of the sewer and piping connections between the various plant units.

j. Laboratory and Control House: A central building housing the electrical pumps, equipment controls, plant laboratory and operating records. A complete schedule of laboratory equipment for plants of various types is contained in Appendix "B".

7-36. SEWAGE FLOWS:

a. Average 24-Hour Sewage Flows: The average daily sewage flow to be used for the design of sewage treatment plants will be determined by multiplying the total tributary population, increased by the proper capacity factor, as set out in Paragraph 7-37 by the following per capita daily rates of flow:

Type of Unit	Gallons per Capita per Day			
	Permanent Posts	Mobilization Type	T. of O. Type	Field Training Camps
Airfields, Camps, Cantonments and Troop Facilities	100	70	50	35
Hospital Units	100	100	85	70
Plant, Port and Storage Projects (Civilian War Workers)		30 per 8 hour shift 100 for resident personnel		

Additional allowances should be included for ground water infiltration if provision has been made for ground infiltration in the design of the sewers.

b. Average 16-Hour Sewage Flows: The sixteen hour average rate of flow will be 125 per cent of the average rate for 24 hours.

c. Maximum 4-Hour Sewage Flows: The maximum 4-hour average rate of flow will be 175 per cent of the average rate for 24 hours.

d. Minimum 4-Hour Sewage Flows: The minimum 4-hour average rate of flow will be 40 per cent of the average rate for 24 hours.

e. Extreme Peak Sewage Flows: Occasional extreme peak rates will reach 300 per cent of the average rate for 24 hours.

(NOTE: The design of the various elements of the sewage treatment plant will normally be based on average daily rates of flow. For plant, port and storage projects employing large numbers of civilian workers the sewage flow of 30 gallons per capita per day will occur during the eight hour shift the workers are on duty. Sewage treatment plants for such projects should provide for the maximum flow, which will occur during the eight hour shift the greatest number of employees are engaged.)

7-37. SEWAGE CHARACTERISTICS:

a. Airfields, Camps and Cantonments: Data on sewage characteristics at War Projects indicate larger per capita quantities of suspended solids, larger amounts of grease and slightly larger quantities of B.O.D. than is normally found in domestic sewage. The sewage reaching the treatment plant will usually be relatively fresh and have good settling qualities. The settled sewage should be readily amenable to treatment by biological processes. The following characteristics apply to sewage from airfields, camps and cantonments:

ITEM	POUNDS PER CAPITA PER 24-HOURS
Suspended Solids	0.27
B.O.D. (5-day)	0.20
Ether-soluble Matter	0.09

b. Plants, Ports and Storage Projects: The following characteristics apply to sewage from Plants, Ports and Storage Projects:

ITEM	POUNDS PER CAPITA PER 8-HOUR SHIFT	POUNDS PER CAPITA RESIDENT PERSONNEL
Suspended Solids	0.13	0.27
B.O.D. (5-day)	0.10	0.20
Ether-soluble Matter	0.05	0.09

(NOTE: The above per capita sewage strength quantities will remain constant regardless of rates of flow. Provision for additional capacity in the biological processes for reasonable population increases is made by applying the capacity factors outlined in Paragraph 7-38.)

7-38. CAPACITY OF SEWAGE TREATMENT PLANTS:

a. Initial Design Capacity: The initial construction of sewage treatment plants will be based on the authorized military and civilian tributary population, which will be increased by the following capacity factors:

SPECIFIED PROJECT POPULATION	CAPACITY FACTOR
10,000 and less	2.00
20,000	1.50
30,000	1.25
40,000	1.10
50,000 and over	1.00

(NOTE: Standard designs for Sewage Treatment Plants, Drawings Nos. 672-251, 672-252, 672-253, 672-254, 672-255, 672-256 for populations of 1,000, 2,000, 3,600 and 5,000 are based on Theater of Operation construction with a sewage flow of 50 gallons per capita per day and do not include the capacity factor. When these plant designs are used the capacity factors should be omitted since additional capacity can be provided when required by constructing additional plant elements of the necessary size adjacent to initial plant at no appreciable increase in total cost.)

b. Capacity Factor: The capacity factor is applied by multiplying the authorized military and tributary population by the proper capacity factor stated above. This gives the design population and all elements of the plant are based on the design population. The capacity factor is to provide for the following:

- (1) Reasonable increases in population.
- (2) Variations in sewage flows and uncertainties as to actual sewage quantities for projects of the same type.
- (3) Unusual peak flows the magnitude of which cannot be accurately estimated in advance.

7-39. ARRANGEMENT OF UNITS: Plants serving populations greater than 5,000 should be flexible enough to permit operation and treatment with any individual plant unit out of service. This can be accomplished by providing the required capacity for primary settling, filters, final settling and other plant elements in at least two units each and arranging the piping so that any individual unit can be taken out of service. The arrangement of plant units should be such as to permit future enlargement of the plant capacity at a minimum cost and minimum interference with plant operation.

7-40. HYDRAULIC DESIGN: Experience at a number of Army Cantonments indicates considerable variations in the hourly rates of sewage flow. Typical hourly variation curves are attached hereto (Exhibit 3). The design will be based, in general, upon the 24-hour average rate of sewage flow. The hydraulics of conduits and distributor mechanisms should be designed to permit passage of an extreme peak rate of flow of three times the average daily rate of flow.

(NOTE: Provision for peak flows of 300 per cent at the sewage treatment plant may be greater than the capacity of sewers specified in paragraph 7-12 b above. Experience has shown that such rates may be delivered with the outfall sewer flowing under a slight head.)

7-41. SCREENS: Screens will in general be hand-cleaned bar screens. Mechanical screening mechanisms should be installed only where deep pits cannot be avoided. All screens should have a submerged area of at least twice the area of the incoming sewer. If mechanical screening is employed, the installation should consist of one mechanical screening mechanism with a by-pass bar screen. The clear spacing between bars should be as follows:

Hand cleaned	- 1" to 1½"
Mechanically cleaned	- 5/8" to 1"

7-42. GRIT CHAMBERS: Grit chambers, where provided, should be designed for a controlled velocity of one foot per second with a detention period of from 30 to 45 seconds. In general, grit chambers will be hand-cleaned with disposal of grit by burying.

7-43. MEASURING DEVICES: Devices for measuring sewage flows will be installed in all plants. For plants serving a population of 5,000 or less recording and totalizing equipment will not be required. For plants serving a population greater than 5,000, equipment for recording, indicating and totalizing the flow should be provided. If the sewage is pumped into the treatment works, the measuring devices preferably should be placed ahead of the pumping station in order to record the hourly variations in sewage flows. The following devices have been found satisfactory for measuring sewage flows:

Parshall Flume
Rectangular Flume, Palmer-Bowlus
Venturi meter
Weir

7-44. PRIMARY SEDIMENTATION TANKS: Primary sedimentation tanks should have sufficient volumetric capacity to provide the following displacement periods based upon average daily rates of flow through the tanks including any recirculation of sewage or sludge:

TYPE OF SEWAGE TREATMENT	Displacement Period in hours based upon 24-Hour Average Rate of Flow
Plain Sedimentation (no recirculated flow)	2.5
Standard Trickling Filters	2.5
High Capacity Filters	2.5
Activated Sludge	1.5
Contact Aeration	2.5

NOTE: For Plant, Port and Storage Projects, a displacement period of 2 hours should be provided on the basis of the average hourly rate for the 8-hour period when the maximum non-resident personnel will be contributing.

7-45. TRICKLING FILTERS:

a. Determination of Applied B.O.D.: In determining the amount of B.O.D. applied to trickling filters, the amount of B.O.D. of the raw sewage may be assumed to be reduced by 35 per cent by prior settling through primary sedimentation tanks.

b. Low Capacity Trickling Filters: Standard or low capacity trickling filters are assumed to provide complete treatment. Standard or low capacity filters should be designed for loadings not to exceed 600 pounds per day of applied B.O.D. per acre foot for filters not greater than 6 feet deep.

c. High Capacity Trickling Filters: High capacity trickling filters are assumed to provide an intermediate degree of treatment. The B.O.D. loading and the recirculation rate of settled sewage for high capacity trickling filters should be determined by the type of treatment selected. The B.O.D. loading should not exceed 3,000 pounds per day per acre foot for filters not greater than 6 feet deep. The development of original designs to overcome patented processes or devices is, in general, considered undesirable. Where it is determined that the use of high capacity filters will result in economies, it is suggested that the design data set forth herein be strictly followed and that the manufacturers' recommendations on the required equipment and processes be followed. This will make it possible to fix responsibilities and require guarantees covered by performance bonds. The use of such processes should provide for competitive bidding on equipment.

7-46. ACTIVATED SLUDGE: Aeration tanks for activated sludge plants should have displacement periods, based upon the average daily rate of sewage flow to which is added an allowance of 25 per cent for return sludge, as follows:

	<u>Hours</u>
With compressed diffused air	8.0
With mechanical aeration	12.0

7-47. CONTACT AERATION:

a. Tank Design: Contact aeration tanks should be designed to provide for frequent sludge removal and arrangements should be made to permit ready removal of a sufficient number of contact plates for access to air grids for cleaning and to permit repairs to sludge removal equipment if such equipment is installed.

b. Tank Capacity: Tanks should be designed of such capacity and in such a manner as to provide not less than 156 square feet of contact media surface per pound of applied B.O.D. per day for plants in the South and 175 square feet of contact media surface per pound of applied B.O.D. per day for plants in the North. If plates are used, the spacing between media surfaces should be approximately 1-1/2 inches.

c. Air Requirements: Provision should be made for supplying not less than one and one-half (1-1/2) cubic feet of free air per gallon of sewage treated for the two-stage process and not less than three quarters (3/4) of a cubic foot of free air per gallon of sewage for the single-stage process.

7-48. FINAL SEDIMENTATION TANKS:

a. Requirement: Final settling is required following trickling filters, activated sludge aeration tanks and contact-aeration tanks.

b. Final Sedimentation Tank Design:

(1) The final sedimentation tanks for all types of treatments should have sufficient volume to provide a displacement period of two and one-half (2-1/2) hours based on the average daily rate of sewage flow through the tanks including any recirculation of sewage or sludge.

(2) In case of two-stage filtration or aeration, the final sedimentation tanks should have the foregoing capacities in addition to any intermediate settling between stages of biological treatment.

(3) Reasonable sedimentation tank depths should be from eight (8) to ten (10) feet with some deviation from these in special cases. Overflow rates should not exceed 800 gallons per square foot of tank area per day, based on the average daily rate.

7-49. SLUDGE DIGESTION TANKS:

a. Capacities: Capacity in digestion tanks should be provided in the following amounts:

TYPE OF SEWAGE TREATMENT	Digestion Tank Capacity - Cubic Feet per Capita	
	Heated Tanks	Unheated Tanks
Plain Sedimentation (No recirculated flow)	2.0 cu. ft.	3.0 cu. ft.
Plain Sedimentation with Chemical Precipitation	3.0 cu. ft.	4.5 cu. ft.
Standard or Low Capacity Trickling Filters	3.0 cu. ft.	4.5 cu. ft.
High Capacity Trickling Filters	3.0 cu. ft.	4.5 cu. ft.
Activated Sludge	4.0 cu. ft.	6.0 cu. ft.
Contact-Aeration	3.0 cu. ft.	4.5 cu. ft.

NOTE: Initial designs which include the capacity factor will usually be based on the use of heated digestors. In order to conserve critical materials the heating equipment may be omitted except in extremely cold climates until such time as the full capacity of the digestor is required.

b. Disposal of Supernatant Liquor: Piping arrangements should be provided to discharge supernatant liquor from the sludge digestion tanks into the influent ahead of the primary sedimentation tanks and also for discharging the supernatant liquor into the sludge drying beds.

7-50. SLUDGE DISPOSAL: In general, the sludge resulting from sewage sedimentation should be disposed of by digestion and air drying. Mechanical dewatering and incineration are not considered economically justifiable except in special cases of industrial waste treatment where the sludge may contain sufficient toxic materials to prevent satisfactory digestion. Air drying of digested sludge should be provided by specially constructed open sludge drying beds or by the preparation of undrained drying areas.

7-51. DESIGN OF SLUDGE DRYING BEDS: Open sludge drying beds, constructed with underdrains, selected filter material (gravel and concrete sand) and wooden or concrete side walls and partitions, should provide approximately 1.0 square foot of bed surface per capita. Where local conditions permit sludge drying on natural drainage areas, such areas should be used. These should be prepared by building small earthen dykes around leveled areas without underdrains or specially selected filter materials. Areas ranging from 2.0 to 3.0 square feet of prepared surface per capita should be provided for natural drainage areas.

7-52. IMHOFF TANKS:

a. Sedimentation Compartments: Where Imhoff tanks are used, the entire cross sectional area of the sedimentation compartments should have the same displacement volume as specified hereinbefore for primary sedimentation tanks. Velocities through the sedimentation chamber should not exceed 1 foot per minute at peak flows. (See Paragraph 7-37 e.)

b. Sludge Compartments: Sludge compartments of Imhoff tanks should have approximately the same per capita volume as specified hereinbefore for unheated separate sludge digestion tanks. Sludge capacity should be computed from a line 18 inches below the slot of the flow-through chamber.

7-53. SEPTIC TANKS: Septic tanks may be used to serve small or scattered installations where the effluent can be disposed of by subsoil irrigation, leaching wells or underground filters. In general, this method of treatment should be limited to installations where the total contributing population does not exceed 500.

a. Design of Septic Tanks: Septic tanks should be constructed of wood or non-reinforced concrete with wood covers and baffles and should have sufficient capacity to provide approximately 24 hours detention at the average rate of sewage flow. From 15 to 25 per cent should be added to the required volume for sludge space, with the greater space being provided in the smaller tanks. The length of the tank should be not less than two nor more than three times the width and the liquid depth should be not less than 4 feet for the smaller tanks and 4-1/2 to 6 feet for the larger ones. Tanks of less than 500 gallons capacity are of questionable value and should not be used. Manholes should be provided over both inlet and outlet pipes and over the low point in the tank bottom.

b. Dosing Tank: Dosing tanks with automatic sewage siphons should be provided for all septic tanks handling the sewage from 20 or more persons and where the effluent is disposed of in tile fields or subsurface filters. Dosing tanks are not necessary where the effluent is discharged into leaching trenches or leaching wells. Dosing tanks should be designed to discharge a volume equal to about 80 per cent of the volumetric capacity of the disposal lines comprising the tile field or filter. The dosing tank can usually be constructed the same width and as a part of the septic tank. The high water level should be not less than 3 inches below the level of the sewage in the septic tank.

7-54. SUBSURFACE IRRIGATION: Subsurface irrigation is the most satisfactory means for disposing of the effluent from a septic tank installation where the soil and site conditions are suitable. It consists of the application of the settled sewage to the upper layers of the soil by means of open joint 4 inch agricultural tile.

a. Design of Subsurface Irrigation: The trenches for the tile lines should be about 18 inches wide and preferably not over 2 feet deep. The tile should be completely surrounded with crushed stone or gravel, the full width of the trench and about 12 inches deep, the invert of the tile being about 6 inches above the bottom of the trench. The upper half of each tile joint should be covered with tar paper to prevent the entrance of sand or gravel. The tile lines should be spaced from 5 to 10 feet apart depending on the soil absorption and the laterals should not greatly exceed 100 feet in length. The lateral grades should be about 0.3% when dosing tanks are used and 0.5% when not used and every effort should be made to procure an equal distribution of the sewage in all lines of the tile.

7-55. LEACHING WELLS: Leaching wells may be used in connection with septic tank installations where the absorptive quality of the upper soil or the topography does not permit the economic use of a tile field but where the absorption of the subsoil is sufficiently great to permit the disposal of settled sewage. Leaching wells should never be used in the vicinity of shallow wells or springs or where the pollution of ground water is objectionable.

7-56. SUBSURFACE SAND FILTERS: Subsurface sand filters may be used in connection with septic tank installations where conditions are unfavorable to the use of either subsurface irrigation fields or leaching wells for the disposal of the tank effluent.

a. Design: Subsurface sand filters may be constructed as individual trenches or in the form of rectangular beds. In either case they consist of distribution tile, filter medium, effluent collecting tile and effluent discharge line. A bed of not less than 30 inches of clean medium sized sand should separate the distribution and effluent lines in addition to the gravel surrounding these lines. Distributor lines should be laid level and collector lines at approximately 0.3 per cent grade. Subsurface sand filters should be designed on the basis of one gallon per square foot of filter surface per day and dosing chambers will be required.

7-57. SOIL ABSORPTION TEST: In order to determine the suitability of any area for subsoil effluent disposal, test holes approximately 1 foot square should be dug to the proposed depth of the tile or leaching trench at several points and be filled with water to a depth of about one foot. After this water has seeped away and while the bottom of the hole is still wet, it should be filled with water to a depth of 6 inches and the average time required for the water level to drop one inch be noted. The amount of tile lines or area of leaching trench or leaching well required to dispose of the effluent may be computed from the following table:

TIME IN MINUTES REQUIRED FOR WATER TO FALL 1 INCH IN TEST HOLE	ABSORPTION IN GALLONS PER DAY	
	PER SQ. FT. OF TRENCH BOTTOM IN TILE FIELDS	PER SQ. FT. OF PERCOLATION AREA IN LEACHING WELLS
1	4.0	5.3
2	3.2	4.3
5	2.4	3.2
10	1.7	2.3
30	0.8	1.1
60	0.6	0.8

7-58. CHLORINATION: (See Paragraph 7-35 g.)

a. Points of Application: Chlorination will be provided only when specifically requested in writing by the State Department of Health. Where chlorination is required, provision should be made to permit application of chlorine solution with relation to particular installations as follows:

- (1) Ahead of the primary sedimentation tanks
- (2) Ahead of the trickling filters
- (3) Ahead of final sedimentation tanks and
- (4) Following final sedimentation tanks.

The chlorination equipment should be the solution type and when installed an adequate supply of spare parts should be provided. (Reference: Specification for Theater of Operations (Modified) and Mobilization Construction, Equipment WS-901 and WS-902.) Capacity for a maximum rate of 80 pounds per million gallons for the daily average rate of sewage flow should be provided.

b. Chlorine Contact Tank: When chlorination of the final effluent is required a contact tank should be provided following the application of the chlorine to permit the chlorine to act on the organic matter in the effluent. Contact time of fifteen minutes displacement at the average 4-hour peak rate of flow should be provided by a baffled contact tank unless there is sufficient length of outfall to provide for this detention.

7-59. MECHANICAL EQUIPMENT: It is important that designs be simplified as much as possible and preference given to types of treatment which require the use of a minimum amount of mechanical equipment. However, large plants may require several items of equipment and careful attention should be given in the preparation of plans and specifications in order to secure the maximum possible competition among bidders.

a. Sludge Removal: Mechanical equipment for the removal of sludge from sedimentation tanks is available for either rectangular or round tanks. To permit rapid construction, bids on the equipment should be received at the beginning of the design and final designs completed only for the type of tanks which will receive the equipment purchased.

b. Scum Removal: Scum is usually removed from the surface of the sedimentation tanks by the same mechanical equipment which removes the sludge. Scum removal equipment should be provided for final sedimentation tanks following high capacity filters.

c. Sludge and Scum Pumps: Specifications for pumps to handle sludge and scum should require sturdy construction. The motors for the operations of these units should be of ample power, perhaps a little above rather than below the manufacturer's rating.

d. Digestion Tanks: In general, covers for digestion tanks are desirable for the collection of gas and to submerge the scum which would normally accumulate. Floating covers should be of minimum design from the standpoint of the use of critical material. Agitators should be omitted in connection with fixed covers whenever possible. Heating coils, boilers and other equipment for the utilization of digestion tank gas for the heating of digestors should be omitted whenever possible. Initial designs, which will include the capacity factor, will usually be based on heated tanks but the heating facilities may be omitted except in cold climates until such time as additional digestor capacity is required. The gas can then be used for the generation of steam which can be introduced into the sludge being pumped to the digestor.

e. Flame Protection: Flame traps should be placed as closely as possible to points of burning gas. Waste gas burners should be at least 30 feet from any structure.

f. Drains: All tanks, including chlorine contact tanks, should be provided with drains or pump connections to permit dewatering. Sludge pumps can usually be utilized for this purpose and the piping arrangement should permit the tank contents to be returned ahead of the primary sedimentation tanks.

7-60. OPERATING INSTRUCTIONS: A detailed set of instructions, including appropriate sketches explanatory of the operation of the various items of equipment and plant units should be provided. Five copies of these instructions should be furnished for distribution to the Plant Operator, the Post Engineer, the District Engineer, the Division Engineer and the Office of the Chief of Engineers. General supervision of operation by the Designing or other Sanitary Engineer, or a Chemist especially experienced in the operation of a plant of the type to be constructed, is desirable for a period of at least three months, in order to provide satisfactory operation during the transition period from construction to operation. Formal monthly reports as prescribed in the Repairs and Utilities Manual should be prepared, showing records of adjustments, correction and operation results during the starting period.

7-61. MANUFACTURER'S GUARANTEE AND SERVICE INSPECTION AND TEST: The specifications for the major items of equipment should require the equipment manufacturer to guarantee the equipment against defective materials and workmanship for a period of one year and to furnish the services of a factory representative experienced in the erection of equipment, to supervise the installation and test the operation of the equipment units furnished by his company. In case of any difficulty with operation, the factory representative should make additional visits as may be required to correct the operating difficulties.

7-62. SEWAGE TREATMENT PLANT LABORATORY: Each plant should be provided with a laboratory, equipped with furniture and materials with which routine tests can be made as prescribed in Repairs and Utilities Manual. Classification of Army Sewage Treatment Plants by type and size is given in Appendix "A", attached hereto. Appendix "B" is a list of Recommended Laboratory Furniture, and Appendix "C" is a Schedule of Recommended Laboratory Equipment for plants of various types. A list of Recommended Laboratory Chemicals and Reagents for Plant Laboratories is given in Appendix "D", and Appendix "E" is a suggested list of Tools for Plant Maintenance.

7-63. DESIGN ANALYSIS: A preliminary flow chart setting forth the tentative design factors will be submitted in accordance with the provisions of Paragraph 703.33 a (b) of Orders and Regulations. A design analysis, required by Paragraph 703.33 a (Revised to November 2, 1942), Orders and Regulations, Corps of Engineers, will be prepared to accompany all plans and specifications for sewage treatment plants. The Design Analysis will set forth the design population, the basis for the selection of the degree of treatment to be provided, the basis of design for each unit of the treatment plant and will be accompanied by a final flow chart.

APPENDIX "A"

CLASSIFICATION OF SEWAGE TREATMENT PLANTS
FOR
SCHEDULING LABORATORY FURNITURE AND EQUIPMENT

Plant Types	Classification			
	Per 1,000 Population Capacity	38 &	12-38	6-12
Over				1.5-6
Complete Treatment with Separate Sludge Digesters	A	A	B	C
Primary Tanks and Separate Digesters- Primary Treatment Only	A	B	C	C
Imhoff Tanks with Trickling Filter or Slow Sand Filter	B	B	C	D
Imhoff Tanks Only, or Sand Filters Only	-	C	D	D

APPENDIX "B"

RECOMMENDED LABORATORY FURNITURE FOR ARMY SEWAGE TREATMENT PLANTS

For Type "A" Plants	Items 1, 2, 3 and 4
For Type "B" and "C" Plants	Items 2, 3, and 5
For Type "D" Plants	No Furniture

Item 1. One (1) Industrial Chemistry Laboratory table 72" long, 48" wide, 36" high, equipped with 32 drawers 10-1/2" wide, 16" deep and 6-3/4" high, 4 cupboards 10-1/2" wide, 18" deep and 27-3/4" high; one (1) bottle rack 68" long, 10" wide and 18" high, 1 drain trough of lead lined or stone construction, 66" long, 6" wide and 3" to 6" high, and 1 stone sink 20" long, 12" wide and 12" deep. The cabinet shall be built of oak, the top shall be Shelstone or Alberene stone 1-1/4" thick. The bottle rack shall be black carbonized. Equipment, 3 straight-way water cocks, one bib water cock and one set of sink fittings. Table to be equivalent to that of the following companies:

E. H. Sheldon & Co., Muskegon, Michigan - No. 11268
W. W. Kimball Co., Chicago, Illinois - No. 502
Hamilton Mfg. Co., Two Rivers, Wis. - No. L-512

Item 2. One (1) Balance Shelf, 3' long x 2' wide; oak construction except for 1-5/8" thick birch, black carbonized top; equipped with drawer 21" wide, 15" deep, 3-3/4" high. Shelf to be equivalent to:

E. H. Sheldon & Co. - No. 12520
W. W. Kimball Co. - No. 682
Hamilton Mfg. Co. - No. L-1174

Item 3. One (1) Supply Case, 48" wide, 15" deep, 80" high, upper section glazed 44" wide, 60" high with 3 adjustable shelves; cupboard section 44" wide, 12" deep, 13" high, of oak.

E. H. Sheldon Co. - No. 41040
W. W. Kimball Co. - No. 9562
Hamilton Mfg. Co. -

Item 4. One (1) Lower Section Cupboard Unit 37-5/8" long x 24" wide x 36" high, containing 1 double cupboard 34" wide x 28-1/4" high x 20-5/8" deep, with 1 stone sink 14-1/4" long x 10" wide x 8" deep with 1 set of drain fittings, 1 cold water pantry cock and 1 double electric receptacle for 110-V A.C., table top to be scored to drain to sink.

E. H. Sheldon Co. -
W. W. Kimball Co. -
Hamilton Mfg. Co. - No. L-804

All furniture shall be oak construction, natural finish throughout, except table tops, which are to be 1-5/8" birch black carbonized.

Item 5. One (1) Chemistry Laboratory table 60" to 96" long, 36" high, 30" wide, with an integral sink on one end, equipped with a reagent shelf and constructed for installation against wall with cupboards and shelves below on one side only. Top to be Shelstone or Alberene stone.

APPENDIX "C"

RECOMMENDED LABORATORY EQUIPMENT FOR ARMY SEWAGE TREATMENT PLANTS.

QUANTITY	Type of Plant A & B C D	DESCRIPTION	CATALOGUE NUMBERS		
			E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific Co.
1	1	Analytical Balance, Chainomatic, notched beam, student model	S-2675	1020	
1	1	Balance weights, set 1 gm to 100 gm, Gold plated, no fractional, w/case	S-4045	8180-B	2-215
1	1	Balance, Harvard, metric, 1kg Beam grad. to 1/10 gm	S-3215	3470	2-035
1	1	Balance weights, metric, Class C, 1 gm to 1000 gm	S-4285	9140	2-300
1	1	Drying Oven, Thelco No. 14, 110 V	S-64055	95000	13-265
1	1	Furnace Muffle, Elec. Hoskins, Type F. D., Size No. 202-110 V	S-36855	13675-A	10-510
1	1	Rheostat for muffle furnace	S-36875	13678-A	
1	1	pH Meter, one-two type control portable electrometer for pH determination w/extral glass electrode & buffer soln. Cameron, Beckman, Coleman, or equal			
1	1	Hydrogen Ion Apparatus Color Comparator-pH, LaMotte or Hellige w/Bromthymol Blue Stds.	S-41725	21500-H	
1	1	pH Standards, LaMotte or Hellige Cresol Red, Range K	S-41735	21550-K	
1	1	Indicator Solution Cresol Red, LaMotte or Hellige 100 ml	S-41745	21560-K	5-985-A
1	1	Mechanical Refrigerator, sealed type mechanism, 6 cu. ft.			
3	3	Imhoff Cone	S-84125	29015	15-440
1	1	Incubator, 20°, Mechanical cooling, Frigidaire type, - or Eimer & Amend water bath type			
1	1	Sampler for Sewage and Sludge, brass, w/chain, pump and air hose			Pacific Flush Tank Co., Bulletin #133

APPENDIX "C" (CONT'D.)

QUANTITY	DESCRIPTION	CATALOGUE NUMBERS			
		E. H. Sargent Co.	Central Scientific Co.	Fisher Scientific Co.	Scientific Co.
Type of Plant A & B C D					
1	Corks XXX Assorted sizes, bag of 100	S-23055	12402	7-785	
2	Funnels - Analytical 75 mm	S-35315	15055	10-237	
2	Short stem - 150 mm	S-35305	15070	10-320	
2	Buechner 2 A ***	S-35555	18590	10-355	
*** 1	Glass tubing, 5 to 10 mm - assorted per 16	S-40075	14075	11-350	
1	Glass Rod, 6 mm per 16	S-40095	14050	11-375	
1	Glass T-tubes 8 mm c.d.	S-82725	15650	15-325	
2	Pipettes-Transfer 100 ml	S-69505	16355	13-650	
2	50 ml	"	"	"	
2	25 ml	"	"	"	
2	10 ml.	"	"	"	
2	5 ml	"	"	"	
2	1 ml	"	"	"	
6	Pipettes, Mohr, 10 ml, grad. to 1/10 ml	S-69555	16325	13-665	
2	Rings, Iron, 4 in.	S-73045	18005	14-050	
2	3 in.	"	"	"	
4	Supports, Iron, large	S-78305	19005	14-670	
1	Spatula, stainless steel - 100 mm	S-75245	18755	14-365	
1	Spoon, Horn, 150 mm	S-75175	18775	14-425	
2	Thermometers - 10°C to 110°C	S-80005	19240	14-985	
1	10°C to 250°C	"	"	"	
2	10°F to 220°F	S-80015	19280	14-990	

*** For Activated sludge Plants only.

APPENDIX "C" (CONT'D.)

QUANTITY	DESCRIPTION	CATALOGUE NUMBERS			
		E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific Co.	Scientific Co.
2	Crucible Holder, Walter	S-24475	18110	8-285	
4	Graduated Cylinders, double grad. 1 liter	S-24685	16105	8-555	"
1	500 ml	"	"	"	"
1	250 ml	"	"	"	"
2	100 ml	"	"	"	"
1	100 ml	S-24765			
1	Low Form	S-25015	14560	8-600	
1	Dessicator, Schiebler, with plates, 250 mm	S-25505	18575-2	8-690-C	
6	Dishes, evaporating, Coors, porcelain, 150 ml	S-32225	88325	9-725	
2	Files, triangular tapered, 4"	S-32915	13250	9-795	
12	Filter paper-No. 500 per pkg. of 100-9 cm	"	"	"	
2	12.5 cm				
6	Flasks-Erlenmyer-Pyrex 500 ml	S-34355	14905	10-040	
6	Flasks 250 ml	"	"	"	"
2	Flasks, filtering, side tubulation 500 ml	S-34375	14985	10-175	
2	Flasks, Volumetric 1 liter	S-34805	16220	10-200	
1	500 ml	"	"	"	"
2	250 ml	"	"	"	"
4	200 ml	"	"	"	"
2	100 ml	"	"	"	"
1	Flask, Volumetric, 200 ml - Large mouth for D. O.	S-34995	16290	10-240	
1	Filter, Sedgewick, Kastner Graduated for B.O.D. D.	S-84015	29030	15-400	
1	Plate, Spot, size 00 Plate, Porcelain	S-70025	18600	13-745	
		S-60985	18600	13-745	

APPENDIX "C" (CONT'D.)

QUANTITY	DESCRIPTION	CATALOGUE NUMBERS			
		E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific Co.	Scientific Co.
2	Tongs, crucible, lock joint-9 $\frac{1}{2}$ " 1	S-82205 S-82215	19620 "	15-185 "	
2	Triangle, Nichrome 2"	S-82445	19705	15-260	
2	Wire Gauze-Chromel 4" x 4"	S-85315	19960	15-585	
20	Rubber tubing, medium wall pure gum per ft. $\frac{1}{4}$ " 10	S-73505 "	18200 "	14-155 "	
10	Rubber tubing, Vacuum, $\frac{1}{4}$ " 10	S-73535	18204	14-175	
1	Filter Pump-Richards Size A 3/8"	S-33565	13205	9-965	
6	Bottles, dropping 30 ml	S-8745	10535	2-980	
1	Funnel Support - 4 place	S-78815	19035	14-740	
1	Brush, Test Tube Med.	S-9995	10972	3-590	
1	Brush, Flask Size B	S-9965	10985	3-570	
1	Mortar & Pestle porcelain - 100 mm	S-62235	17380	12-960	
6	Bottles - 5 gallon	S-8435	10310	2-885	
1	Still-Water, Stokes gas heated	S-27645	12805	9-055	
1	Chlorine Testing Set	S-83825	29255		
12	Automobile radiator hose for water seals per ft.				
8	Milk kettles, ivory enameled, seamless 4 qt. cap. (for sample storage)				

APPENDIX "C" (CONT'D.)

QUANTITY	DESCRIPTION	CATALOGUE NUMBERS		
		E. H. Sargent & Co.	Central Scientific Co.	Fisher Scientific , Co.
Type of Plant				
A & P C D				
2	Beakers, Pyrex, 2 liter	S-4675	14265	2-540
2	1 "	"	"	"
2	600 ml	"	"	"
4	400 ml	"	"	"
4	250 ml	"	"	"
2	50 ml	"	"	"
1/2	Watch Glasses 115 mm 1 doz.	S-83605	15850	2-610
Bottles, Glass stoppered, Flint Glass, Mach. made.				
12	32 oz.	S-8345	10430	2-915
6	16 oz.	"	"	"
72	8 oz.	"	"	"
36	4 oz.			
2	Bottle Washing, Pyrex - 1000 ml	S-9365	10710	3-395
2	Burettes, Geissler, Blue Line-50 ml	S-10635	15925-C	3-700
2	Burners, Tirril with Stabilizer	S-12295	11025-C	3-960
2	Clamps, Burette, Spring Closing	S-19045	12120	5-770
1/3	Clamps, pinch, 1 doz.	S-19045	12180	5-850
3	Stoppers, rubber, assorted sizes, solid per 1b. \$1.00	S-73305	18150	14-130
1	Cork Lorer, brass set 1 to 6	S-23175	12460-B	7-845
12	Crucibles, Coors, size 1, wide form	S-23665	18535	7-955
12	Crucibles, Gooch, size 3, o.7 mm, perforation, Coors Porcelain	S-24315	18565	8-195

APPENDIX "D"

RECOMMENDED LABORATORY CHEMICALS FOR ARMY SEWAGE TREATMENT PLANTS.

QUANTITY	ITEM		
	Type of Plant A & B	C	D
18 Lbs.	9 Lbs.	9 Lbs.	Sulphuric Acid, C. P. " " Tech.
18 Lbs.	9 Lbs.	9 Lbs.	Hydrochloric Acid.
6 Lbs.			Sodium Azide*
100 grams	100 grams	1 Lb.	Sodium Bicarbonate
1 Lb.		1 Lb.	Sodium Carbonate, Anhyd. C. P.
1 Lb.	5 Lbs.	1 Lb.	Sodium Hydroxide Pellets U.S.P.
5 Lbs.	1 Lb.	1 Lb.	Sodium Thiosulphate, Cryst.
1 Lb.	1 Lb.	1 Lb.	Potassium Iodide C. P.
1 Lb.	1 oz.	1 oz.	Potassium Bi-iodate C. P.
1 oz.			Potassium Bi-chromate, Tech.
5 Lbs.	5 Lbs.	5 Lbs.	Manganese Sulphate C. P.
5 Lbs.	5 Lbs.	5 Lbs.	Potato Starch
5 Lbs.	5 Lbs.	5 Lbs.	Methylene Blue (U.S.P.)
5 Lbs.	5 Lbs.	5 Lbs.	Asbestos, Med. fiber, acid washed
5 Lbs.	5 Lbs.	5 Lbs.	Ferric Chloride, C. P. Lump
5 Lbs.	5 Lbs.	5 Lbs.	Copper Sulphate Cryst., Tech.
5 Lbs.	5 Lbs.	5 Lbs.	Chloroform - U.S.P.
100 grams			Orthotolidine
100 ml			Phenolphthalein Indicator
100 ml			Methyl Orange Indicator
Obtain in field - Ampules			Calcium Hypochlorite
5 Lbs.			Calcium Chloride, Anhyd.

* For Secondary Treatment Plants Only.

APPENDIX "E"

TOOL LIST FOR ARMY SEWAGE TREATMENT PLANTS

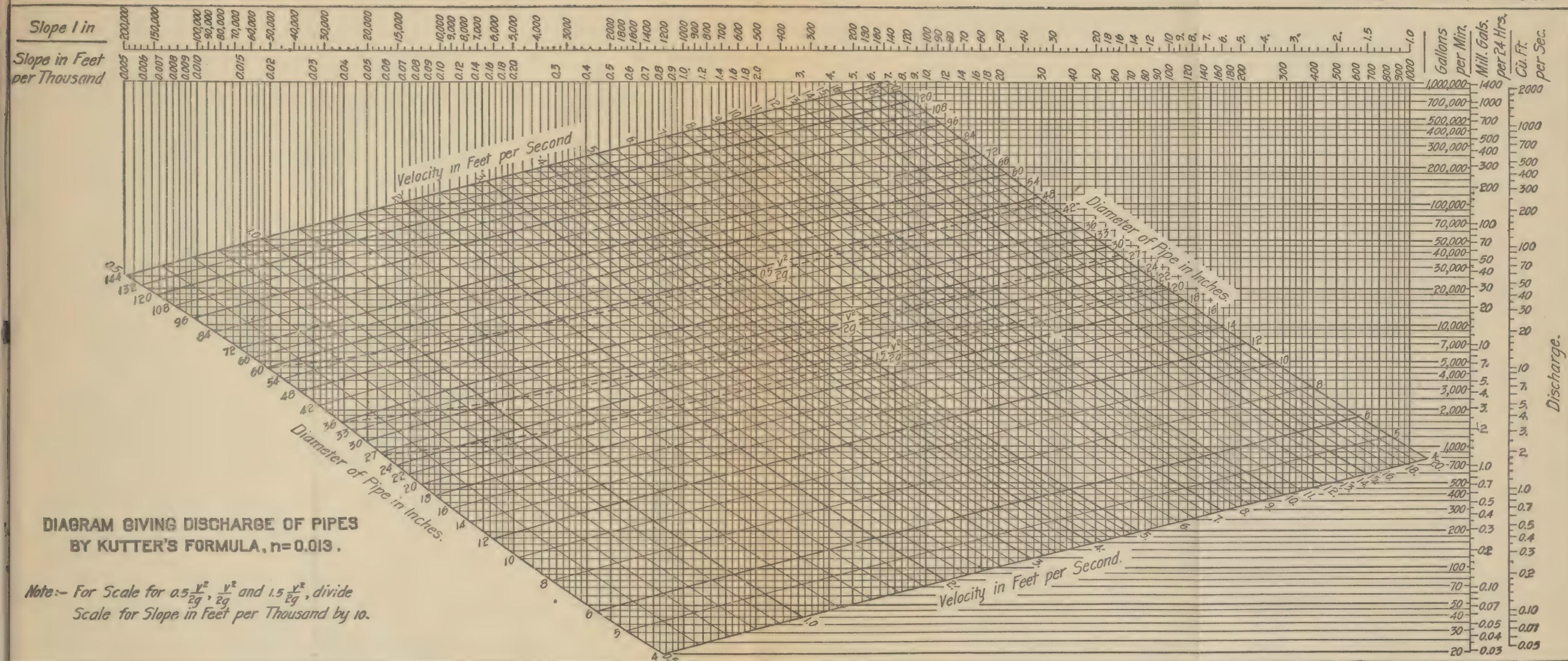
Minimum Requirements for Class A, B & C Plants

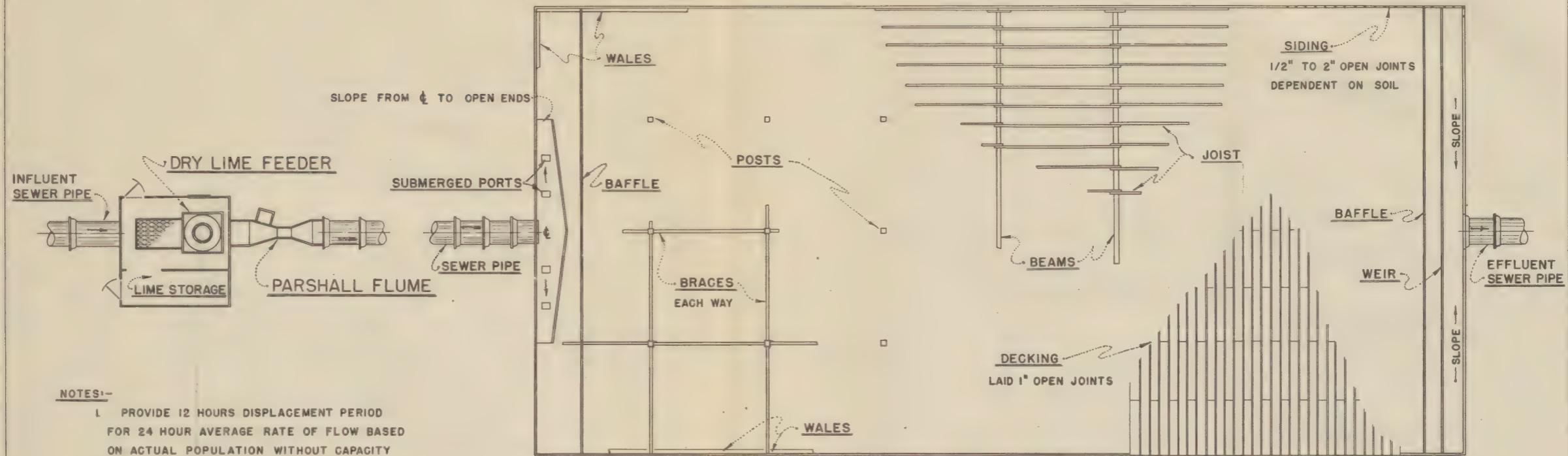
<u>Quant.</u>	<u>Description</u>	<u>Catalogue No. *</u>			
1	Wrenches, pipe, 8"	258	ZAO or equal		
1	" " 12"	2512	ZAO	"	"
2	" " 18"	2518	ZAO	"	"
1	" " 24"	2524	ZAO	"	"
1	Wrenches, Open Double End Set of 9, $\frac{1}{4}$ " to 1"	P 725	ZAO Series or equal		
1	Wrenches, Socket, hex, set of 10 and handle, 7/16" to 1"	P 21	ZAO	"	"
1	Wrench, Crescent Adjustable, 10"	710	ZA1	"	"
1	Vise, Combination jaw and pipe, Swivel base	A 204½	ZA2	"	"
1	Hammer, Blacksmith, 2½ lb.	0272	ZAO	"	"
1	" Ball pein #2	252	ZAO	"	"
1	" Claw #1	211	ZAO	"	"
1	Pliers, Combination, 8"	26	GZA1	"	"
1	Screw Driver, 6"	26	ZAO	"	"
2	File, 10" Mill Bastard	3	ZA3	"	"
1	Cold Chisel, $\frac{1}{4}$ "	200	ZAO	"	"
1	" " 1" extra long	205	ZAO	"	"
1	Hacksaw	1027	ZA1	"	"
1	Hacksaw Blades, doz.	1412	FLZAO	"	"
1	Wrecking Bar, 24"	95	ZAO	"	"
1	Hand Saw, 26", 8 point	80	ZA2-D8	"	"

* H. Channon Co. Cat. #166,
Chicago, Ill.



Discharge of pipes. $n = 0.013$. (John H. Gregory.)

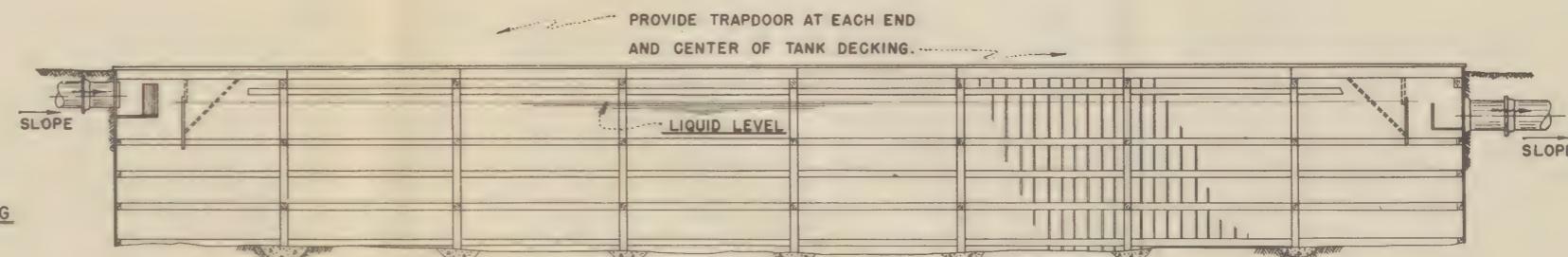
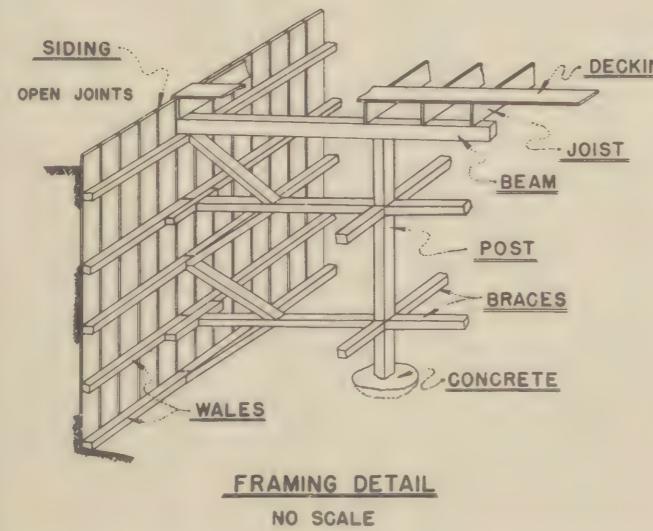




NOTES:-

1. PROVIDE 12 HOURS DISPLACEMENT PERIOD FOR 24 HOUR AVERAGE RATE OF FLOW BASED ON ACTUAL POPULATION WITHOUT CAPACITY FACTOR.
2. LENGTH OF TANK SHOULD BE FROM 2 TO 3 TIMES THE WIDTH, AND AVERAGE LIQUID DEPTH FROM 6 TO 10 FEET.

PLAN

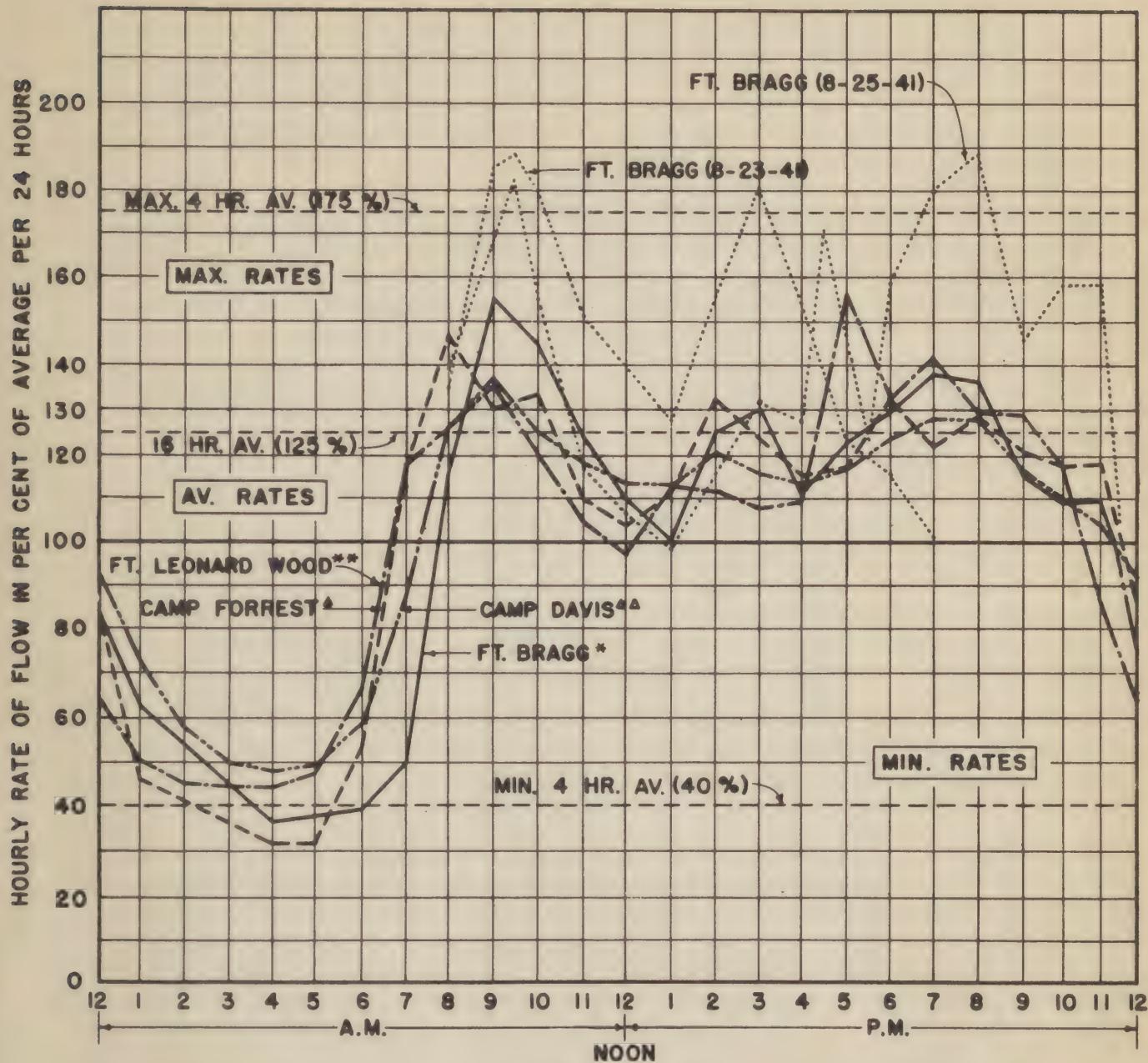


SECTION

SEPTIC TANK
FOR
TEMPORARY SEWAGE DISPOSAL

SEE PARAGRAPH 7-05. a. AND b.

HOURLY SEWAGE FLOW VARIATIONS
FOR
ARMY CAMPS



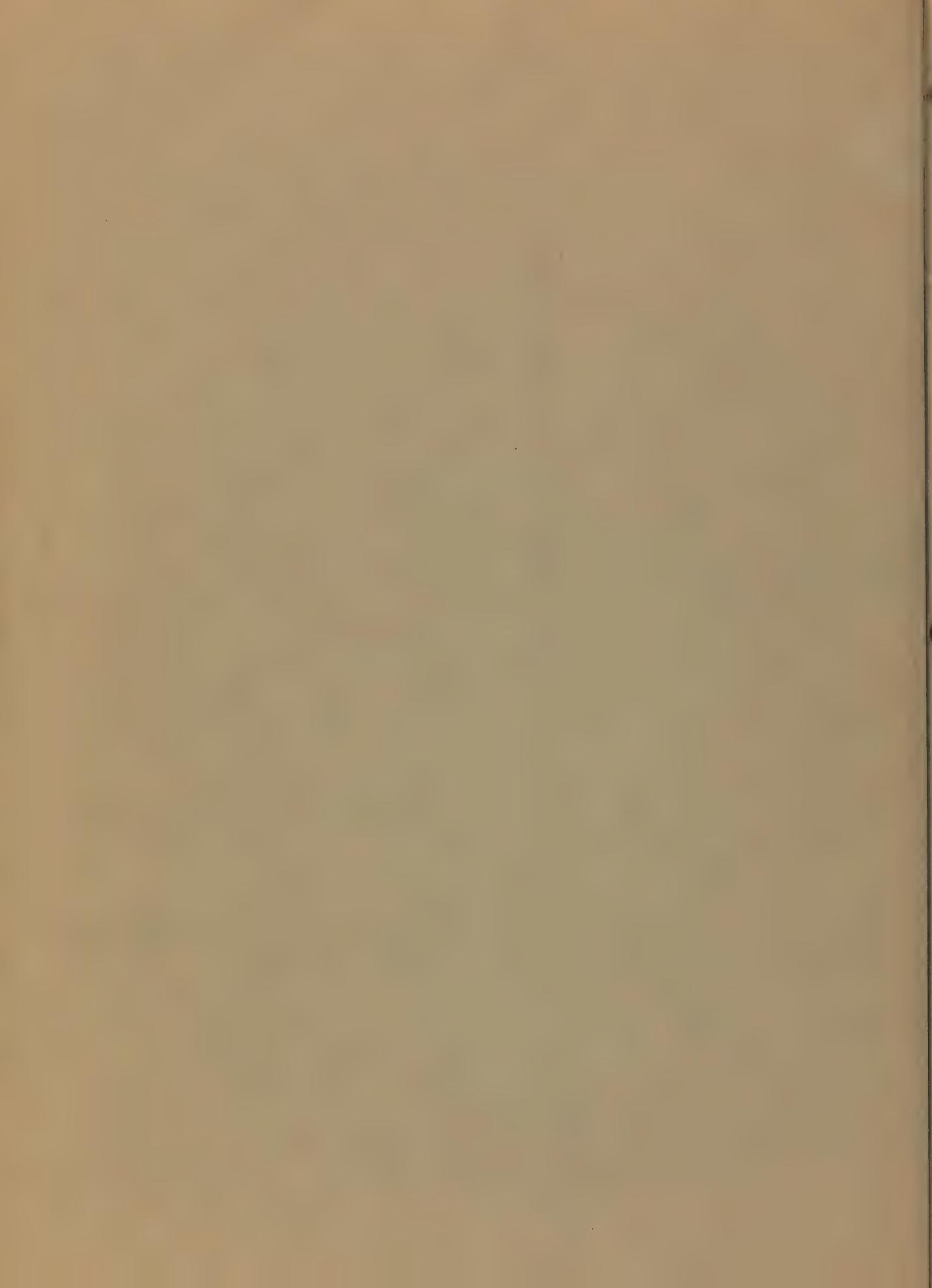
** AVERAGE OF 7 DAYS 9-14-41 TO 9-20-41.

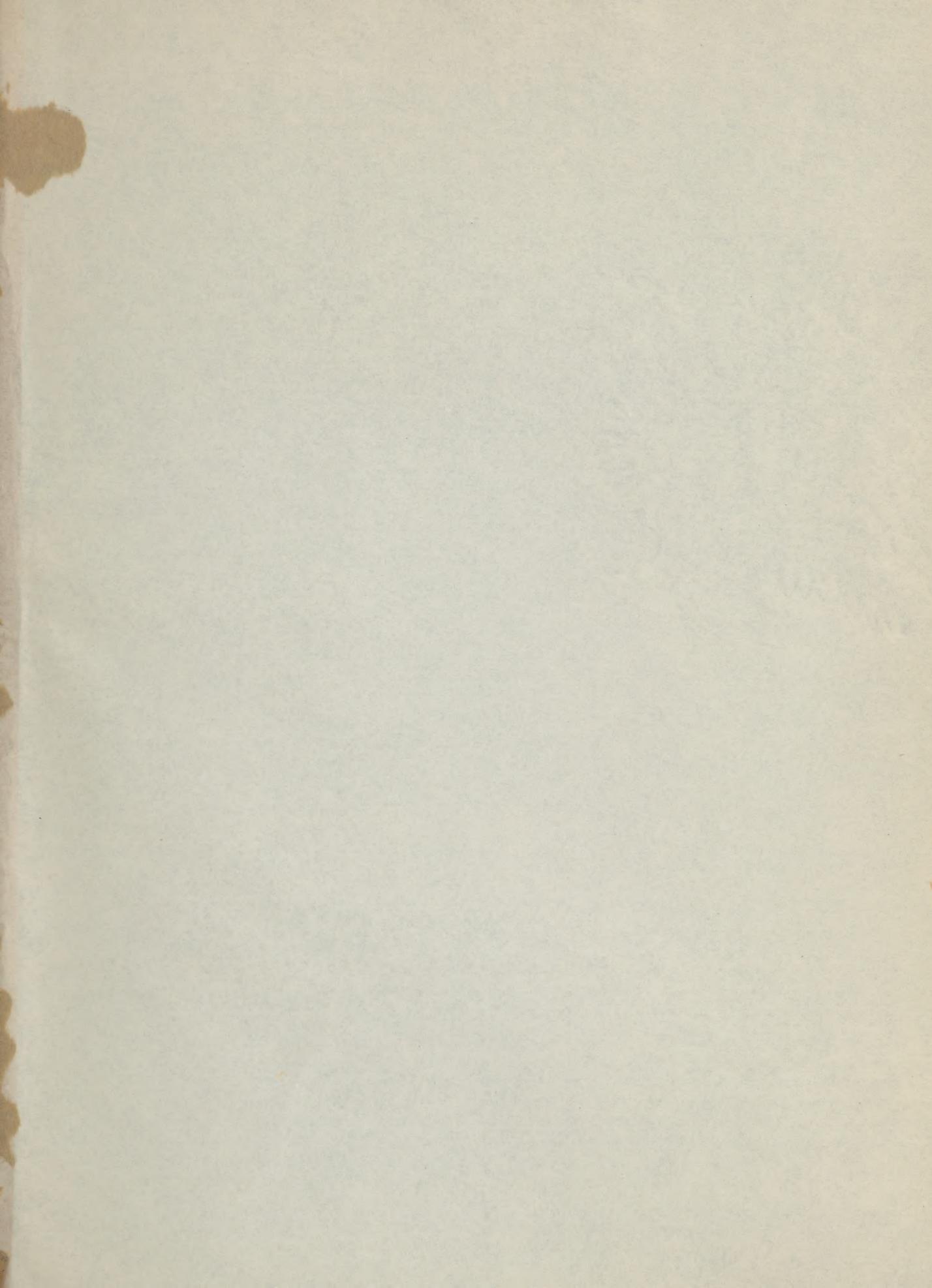
△△ AVERAGE OF 95 DAYS 6-13-41 TO 9-15-41.

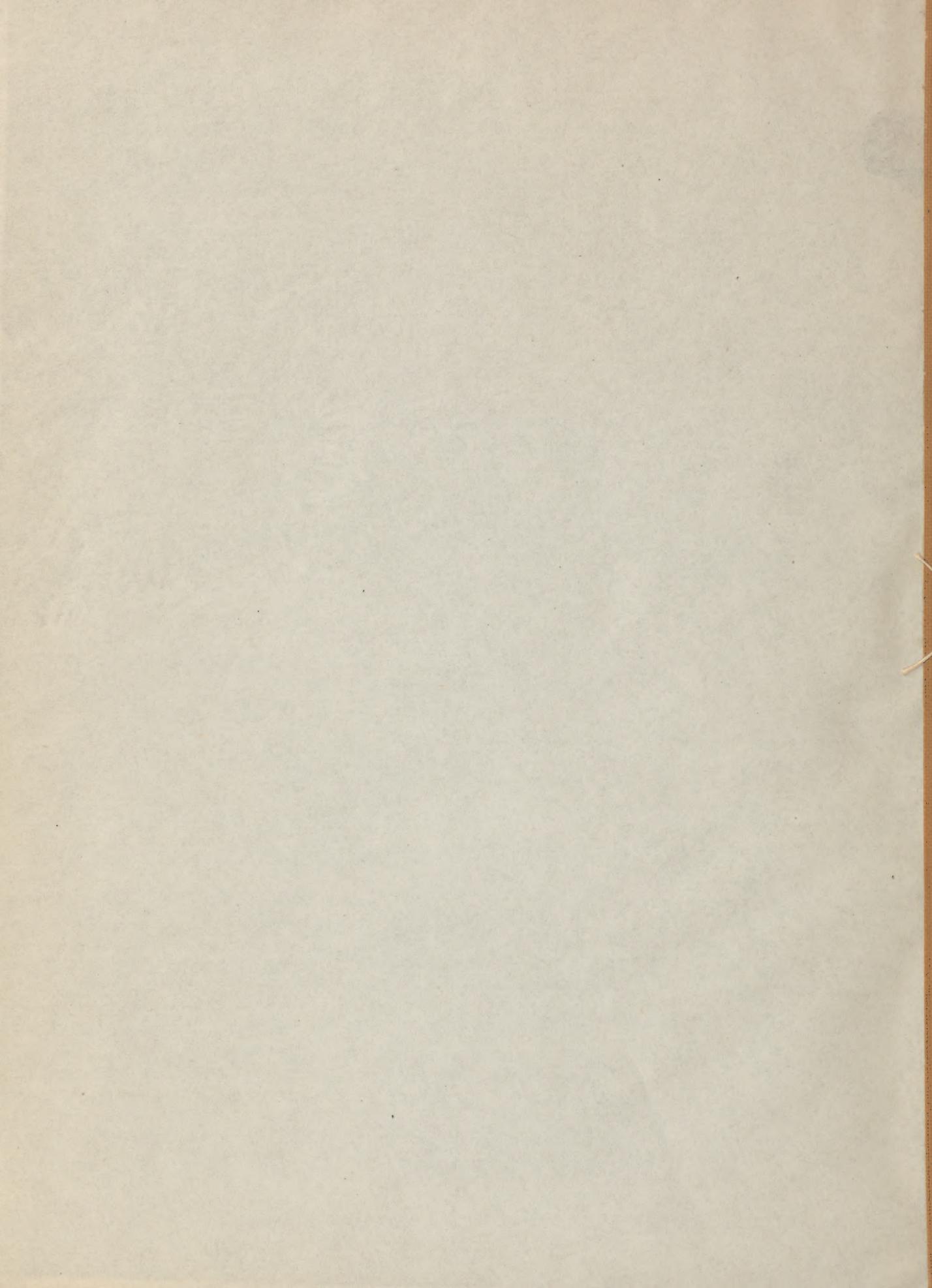
* AVERAGE OF 8 DAYS SELECTED FROM
MONTHLY RECORD OF AUG., 1941.

▲ AVERAGE OF 7 DAYS 7-24-41 TO 7-30-41.

EXHIBIT 3
E.M. JAN. 1943
CHAPTER VII







PRESSBOARD
PAMPHLET BINDER

Manufactured by
GAYLORD BROS. Inc.
Syracuse, N. Y.
Stockton, Calif.

TD 678 qU58d 1944

13820230R



NLM 05096872 8

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